

PB-217 146

WATER QUALITY CONTROL STUDY, BIG SIOUX
RIVER BASIN, IOWA, MINNESOTA AND SOUTH
DAKOTA. STUDY OF THE NEEDS AND VALUE
OF STORAGE FOR WATER QUALITY CONTROL

Federal Water Pollution Control Administration
Kansas City, Missouri

September 1969

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

1.67.2:
848s

2: B48s

PB 217 146



WATER QUALITY CONTROL STUDY BIG SIOUX RIVER BASIN IOWA, MINNESOTA AND SOUTH DAKOTA

**Study of the Needs and Value of Storage
for Water Quality Control**



**UNITED STATES
DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
Missouri Basin Region
Kansas City, Missouri
September 1969**

Reproduced by
**NATIONAL TECHNICAL
INFORMATION SERVICE**
U.S. Department of Commerce
Springfield, VA 22151

I 67.2: U.S. Interior
Federal Water Quality Administration
General Publications

B48a Water Quality Control Study Big Sioux River
Basin - Iowa, Minnesota and South Dakota.

FWPCA Missouri Basin Region Kansas City, Mo.

Sept 1969

no LC#

ERRATA

WATER QUALITY CONTROL STUDY
BIG SIOUX RIVER BASIN
IOWA, MINNESOTA AND SOUTH DAKOTA

page II-2

Paragraph 2 under Conclusions should be deleted and replaced with:

"2. Table VII-1 in the report gives the flows required above Sioux Falls to maintain adequate water quality through the period of study. The increment provided by water quality storage should be only that discharge required in addition to releases for other purposes. The required flows during the month of maximum need (July) vary from 40 c.f.s. in 1970 to 140 c.f.s. in 2070."

page VIII-4

Table VIII-1, line 2 should read:

"Effluent piping (50 yrs.)	possible	\$10,000,000+	\$200,000+ "
----------------------------	----------	---------------	--------------

WATER QUALITY CONTROL STUDY
BIG SIOUX RIVER BASIN
SOUTH DAKOTA, MINNESOTA, AND IOWA

It has been determined from a study of the Big Sioux River Basin that a need exists presently for additional water quality management to meet the requirements of the State Water Quality Standards. The Big Sioux River below Sioux Falls, South Dakota is quite often deficient in dissolved oxygen concentrations.

Prepared by
Federal Water Pollution Control Administration
Missouri Basin Region
Kansas City, Missouri
September 1969

TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	iv
LIST OF FIGURES	iv
I. INTRODUCTION	
Authority	I-1
Purpose and Scope	I-2
Acknowledgments	I-2
II. SUMMARY OF FINDINGS AND CONCLUSIONS	
Summary of Findings	II-1
Conclusions	II-2
III. PROJECT DESCRIPTION	
Location of Reservoirs	III-1
IV. STUDY AREA DESCRIPTION	
Location and Boundaries	IV-1
Geology and Soils	IV-1
Climate	IV-2
V. WATER RESOURCES OF THE STUDY AREA	
Surface Water	V-1
Ground Water	V-4
VI. ECONOMY	
General	VI-1
Past and Present	VI-1
Future	VI-3

TABLE OF CONTENTS (Cont'd)

	<u>Page</u>
VII. WATER QUALITY CONTROL	
Municipal and Industrial Pollution	VII-1
Irrigation	VII-1
Water Quality Criteria	VII-2
Flow Regulation	VII-3
Storage Requirements	VII-4
VIII. BENEFITS OF IMPROVED WATER QUALITY	VIII-1
IX. BIBLIOGRAPHY	IX-1
X. APPENDIX	

LIST OF TABLES

<u>Number</u>		<u>Page</u>
III-1	Pertinent Data - Potential Reservoir Sites . .	III-2
V-1	Hydrologic Characteristics - Big Sioux River .	V-2
V-2	Mean Flow - Big Sioux River at Sioux Falls . .	V-3
VI-1	Historical Population Data	VI-1
VI-2	1960 Employment Data	VI-2
VI-3	Cattle and Hog Slaughter 1960-2070	VI-4
VI-4	Population Projections for Major Urban Areas 1970-2070	VI-5
VII-1	Flows Required at Sioux Falls to Maintain 4 mg/l Dissolved Oxygen	VII-5
VIII-1	Alternative Methods for Achieving Desired Water Quality	VIII-4

LIST OF FIGURES

	<u>Following Page No.</u>
Plate 1 Location Map	VIII-4
Plate 2 Schematic Drawing	VIII-4

I. INTRODUCTION

Authority

In a letter dated March 16, 1967, the Omaha District of the Corps of Engineers requested the Federal Water Pollution Control Administration, Missouri Basin Region, to investigate the present and prospective storage needs for the regulation of streamflow for water quality control in the Big Sioux River Basin.

This study has been made in accordance with the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.). The Federal Water Pollution Control Act states in Section 3b:

"(1) In the survey or planning of any reservoir by the Corps of Engineers, Bureau of Reclamation, or other Federal agency, consideration shall be given to inclusion of storage for regulation of streamflow for the purpose of water quality control, except that any such storage and water releases shall not be provided as a substitute for adequate treatment or other methods of controlling waste at the source."

"(2) The need for and the value of storage for this purpose shall be determined by these agencies, with the advice of the Secretary, and his views on these matters shall be set forth in any report or presentation to the Congress proposing authorization or construction of any reservoir including such storage."

"(3) The value of such storage shall be taken into account in determining the economic value of the entire project of which it is a part, and costs shall be allocated to the purpose of water quality control

in a manner which will insure that all project purposes share equitably in the benefits of multiple-purpose construction."

"(4) Costs of water quality control features incorporated in any Federal reservoir or other impoundment under the provisions of this Act shall be determined and the beneficiaries identified and if the benefits are widespread or national in scope, the costs of such features shall be nonreimbursable."

Purpose and Scope

The purpose of this study is to determine the present and future needs and value of storage for streamflow regulation for quality control in the Big Sioux River Basin, a tributary of the Missouri River.

The study period covers requirements for streamflow regulation for quality control from the present to 2070. The Big Sioux River Basin includes parts of the following counties: Day, Roberts, Grant, Clark, Codington, Deuel, Hamlin, Kingsbury, Brookings, Lake, Moody, Minnehaha, Union and Lincoln in South Dakota; Lincoln, Pipestone, Murray, Rock and Nobles in Minnesota; and Lyon, Osceola, Sioux, and Plymouth in Iowa.

Acknowledgments

The assistance and cooperation of Federal, State, municipal and private organizations is gratefully acknowledged by the Federal Water Pollution Control Administration.

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1. The U. S. Army Corps of Engineers, Omaha District, is investigating the feasibility of five reservoirs in the Big Sioux River Basin as shown on the map in Plate 1 and the schematic drawing in Plate 2 located at the back of the report. Primary purposes of the reservoirs are flood and sediment control, recreation, fish and wildlife, flow regulation for quality control, municipal and industrial water supply, and possibly irrigation.
2. The study area encompasses that part of the basin below the proposed damsites and consists of all or part of the following counties: Lake, Moody, Minnehaha, Lincoln and Union in South Dakota; Pipestone and Rock in Minnesota; and Lyon, Sioux and Plymouth in Iowa.
3. Total area of the Big Sioux River Basin is approximately 9,570 square miles of which 1,970 square miles are noncontributing to the Big Sioux River. The study area located downstream from the reservoirs consists of approximately 4,000 square miles.
4. Total population of the study area in 1960 was 219,935 of which 30 percent was in the Sioux Falls urban area.
5. The 1960 population of the Sioux Falls metropolitan area was 65,466 people; however, the population equivalent (P.E.) of the combined domestic and industrial waste is approximately 500,000. The Morrell Packing Plant discharges to the city municipal plant 4.0 million gallons per day (mgd) of packing house wastes which have a biochemical oxygen

demand (BOD) of 2,000 milligrams per liter (mg/l) and a population equivalent of approximately 390,000.

Conclusions

1. The population of Sioux Falls, South Dakota is projected to increase from 65,466 in 1960 to 350,000 by 2070.
2. To maintain an average of 4.0 mg/l of dissolved oxygen (D.O.) during low flow periods, releases from storage will be required by 2070 to provide a minimum flow above Sioux Falls of 140 cubic feet per second (cfs) during July, the month of maximum demand.
3. Benefits for storage for water quality control are determined as being equal to the cost of the least cost alternative method for achieving adequate water quality. Methods studied included holding ponds, piping the effluent out of the basin, single purpose reservoir, and advanced waste treatment of the city's wastes. The advanced waste treatment alternative was found to be the most economical and benefits are given as \$67,900 per year for a 50-year study period or \$64,100 per year for a 100-year study period.
4. In the event that irrigation becomes a part of the project plan, the need for and value of storage for flow regulation must be re-evaluated to consider the effects of irrigation return flows upon water quality.

III. PROJECT DESCRIPTION

Location of Reservoirs

The proposed reservoirs, as shown on the map in Plate 1 and the schematic drawing (Plate 2), are located in southeast South Dakota and northwest Iowa in the lower reaches of the Big Sioux River, Skunk Creek, Rock River and Little Rock River.

The damsites near Flandreau on the Big Sioux River and near Hartford on Skunk Creek are located above Sioux Falls in South Dakota. These proposed reservoirs, because of location and capacity, are capable of supplying storage to supplement low flows for water quality below Sioux Falls.

The proposed reservoirs are being investigated to determine their feasibility for multipurpose uses such as flood and sediment control with conservation storage for irrigation, recreation, fish and wildlife, water quality control, and municipal and industrial water supply. The locations, drainage areas contributing to the dam, and approximate storage volumes are given in Table III-1.

Table III-1

PERTINENT DATA - POTENTIAL RESERVOIR SITES

<u>Location</u>	<u>Drainage Area</u> (Square Miles)	<u>Storage-Volume</u> (Acre-Feet)
On Big Sioux River - approximately 1 mile east of Flandreau, South Dakota	1,910	410,300
On Skunk Creek - approximately 2 miles northeast of Hartford, South Dakota	291	110,500
On Big Sioux River - approximately 3.5 miles upstream of Canton, South Dakota	3,722	131,000
On Rock River - approximately one- half mile north of Doon, Iowa	916	142,900
On Little Rock River - approximately 6.5 miles upstream from mouth	486	122,300

IV. STUDY AREA DESCRIPTION

Location and Boundaries

The Big Sioux River Basin has a drainage area of about 9,570 square miles of which 69 percent is within South Dakota, 15 percent in Iowa, and 16 percent in Minnesota. Approximately 1,970 square miles of the drainage area, located in South Dakota, are non-contributing. The river originates in northeastern South Dakota and flows southward about 420 river miles to join the Missouri River at Sioux City, Iowa. The Big Sioux River is the boundary between Iowa and South Dakota from below Sioux Falls, South Dakota to the Missouri River.

Only that part of the Big Sioux River Basin drainage below the proposed reservoirs is considered in this report. This area includes the Big Sioux River from Flandreau Reservoir near Flandreau, South Dakota to its mouth; Skunk Creek from the damsite two miles northwest of Hartford, South Dakota to its confluence with the Big Sioux River; a six mile reach of the Little Rock River from the damsite to its juncture with the Rock River and Rock River from the proposed dam two miles upstream from Doon, Iowa to its confluence with the Big Sioux River.

Geology and Soils

The bedrock in the basin is the Precambrian Sioux Quartzite which is exposed in the river valley at Sioux Falls and several other places in the central part of the basin. Cretaceous period formations which overlie the quartzite include Dakota Sandstone, Graneros Shale, Greenhorn Limestone, Carlile Shale, Niobrara Chalk, and Pierre Shale.

The Cretaceous formations are covered by glacial drift which is physically divided into till, outwash and glacial lake deposits. The glacial till is the predominant drift and it consists of a heterogeneous mixture of silt, sand, and large rock fragments in a matrix of clay. The outwash is commonly found in the valleys and plains of the basin and consists of gravel, sand and silt. It ranges in thickness from a few feet to almost 200 feet. Glacial lake sediments occur in small depressions in the till areas. They are usually clay and silt and vary from 4 to 10 feet in thickness.

Recent alluvial deposits of clay, silt, and sand with some gravel occur along both sides of the Big Sioux River and its tributaries and are usually 3 to 15 feet in thickness.

Climate

Average annual precipitation ranges from about 20 inches in the northwestern part of the basin to about 26 inches in the southeastern part. Approximately 75 to 79 percent of the annual precipitation occurs from April to September, with the largest amount occurring in June. Annual precipitation has varied from 13 to 30 inches in the northern part and from 15 to 43 inches in the southern part of the basin.

The average frost-free period ranges from about 130 days in the northern part to about 160 days in the southern part of the basin.

Average annual temperature in the basin varies from 42 degrees Fahrenheit at Watertown, South Dakota to 49 degrees at Sioux City, Iowa. Extremes have ranged from 115° above zero to 42° below zero at Sioux Falls, South Dakota.

V. WATER RESOURCES OF THE STUDY AREA

Surface Water

Principal surface water in the basin consists of the Big Sioux River with many small tributary streams, most of which are on the east side of the Big Sioux. A major tributary is the Rock River which drains an area of about 1,688 square miles in southwestern Minnesota and northwestern Iowa. Although the drainage area of the Rock River is only about 22 percent of the contributing area of the basin, it supplies, on an average, more than 30 percent of the entire annual flow of the Big Sioux River.

Skunk Creek, the principal western tributary of the Big Sioux River, joins the main stem at Sioux Falls. This tributary has a drainage area of about 530 square miles, nearly 7 percent of the entire contributing area. Skunk Creek drainage area supplies about 6 percent of the average flow of the river.

Most of the flow in the system is runoff from the lower portion of the basin where the annual precipitation is higher.

All of the runoff in the contributing area of the basin is uncontrolled. Table V-1 gives the drainage area, years of record, average discharge, minimum and maximum flows, 7 day and 1 day low flows to be expected to occur an average of once every 10 years, for five stations in the study area.

TABLE V-1

BIG SIOUX RIVER BASIN

HYDROLOGIC CHARACTERISTICS

Station	Drainage Area Square Miles	Station Years of Record	Average Discharge (cfs)	Instantaneous Flow from Station Years		Years of Record	1 Day Mini- mum Flow Occurring 1 in 10 yrs.	7 Day Mini- mum Flow Occurring 1 in 10 yrs.
				Minimum (cfs)	Maximum (cfs)			
Big Sioux River near Dell Rapids, South Dakota	5,060	15	270	0.4	15,900	1949-63	0.5	1.0
Skunk Creek near Sioux Falls, South Dakota	520	15	58	0.0	11,500	1949-63	0.0	0.0
Big Sioux River at Sioux Falls, South Dakota	5,750	17	364	0.5	13,800	1944-59	1.0	1.6
Rock River near Rock Valley, Iowa	1,600	15	303	0.0	23,500	1949-63	0.0	0.0
Big Sioux River at Akron, Iowa	9,030	35	848	7.0	50,700	1929-63	15.5	17.5

The streamflow is quite variable. The average flow in the months of March through June is quite high as compared with the other months of the year. The average April flow for the period of record varied from 45 to 6,104 cfs. The mean monthly streamflow in cfs at Sioux Falls is shown in Table V-2.

TABLE V-2
MEAN FLOW - BIG SIOUX RIVER AT SIOUX FALLS,
SOUTH DAKOTA--HISTORICAL RECORD OF 23 YEARS

Month	Mean Flow (cfs)	Month	Mean Flow (cfs)
October	93	April	1228
November	75	May	564
December	47	June	634
January	22	July	397
February	123	August	223
March	671	September	131

Water quality of the Big Sioux River is generally regarded as more acceptable for general purposes than the ground water supplies. The river water is definitely lower in dissolved solids. The nutrient concentrations are high enough to allow extensive algal growths. Coliform counts, indicative of the possible presence of pathogenic organisms, are usually very high in the river below Sioux Falls.

Ground Water

Ground water in useable quantities generally occurs in deposits of glacial outwash and alluvial deposits found along glacial melt water channels and along existing stream valleys. The outwash deposits contain the most significant quantities. Absorption of precipitation is the principal means of recharge for the outwash deposits. Percolation from streams also supplies some recharge.

All of the incorporated municipalities in the Big Sioux River Basin, with the exception of Sioux Falls and Watertown, South Dakota, obtain their municipal water supply from ground water sources. Watertown and Sioux Falls use a combination of surface and ground water. Eighty-five percent of the municipalities have municipal water systems. Only 45 percent of these have treatment plants usually providing iron and manganese removal, disinfection, and softening. The municipal wells range in depth from 20 to 1360 feet with the majority being less than 500 feet. Water from the wells over 800 feet varies widely in chemical quality and is usually more highly mineralized than water from the shallower wells.

VI. ECONOMY

General

Presented in this section are economic and demographic data to be used as a basis for projecting the water needs for municipal and industrial use. The economic data of the study area will provide insight as to the future amounts and characteristics of wastes in the Big Sioux River Basin.

Past and Present

The Big Sioux River Basin study area, dominated by the Sioux Falls Standard Metropolitan Statistical Area (SMSA), has definite urban characteristics. Its population has increased 11 percent from 1940 to 1960 due primarily to the growth of the Sioux Falls SMSA. The Sioux Falls urban population of 65,466 represented 30 percent of the 219,935 total for the study area in 1960.

Other significant urban areas on the Big Sioux River are Dell Rapids, and Flandreau, South Dakota, and Hawarden, Iowa. Table VI-1 summarizes the population of the study areas.

TABLE VI-1
HISTORICAL POPULATION DATA
BIG SIOUX STUDY AREA

<u>Urban Areas on Big Sioux</u>	<u>1940</u>	<u>1960</u>
Sioux Falls, South Dakota	40,832	65,466
Hawarden, Iowa	2,681	2,544
Flandreau, South Dakota	2,212	2,129
Dell Rapids, South Dakota	1,706	1,863
Total Population	195,108	219,935

The general population trend shows a gradual movement of people from rural areas to urban centers. The rural population decrease is more than offset by the increase in the urban population. This urban growth creates increased volume of wastes requiring expansion of municipal waste treatment facilities.

Employment in the study area reflects the trade center role of the Sioux Falls SMSA in the economy of the area. The Sioux Falls SMSA has grown, primarily because it provides trade and services for the entire study area and areas outside the basin in parts of South Dakota, Iowa, and Minnesota. Table VI-2 gives employment data for the study area.

TABLE VI-2

1960 EMPLOYMENT DATA
BIG SIOUX STUDY AREA

	<u>TOTAL</u>	<u>STUDY AREA LESS SMSA</u>	<u>SIOUX FALLS SMSA</u>
Agriculture	21,135	18,130	3,005
Mining	164	91	73
Manufacturing	<u>8,851</u>	<u>3,417</u>	<u>5,434</u>
Total Basic	30,150	21,638	8,512
Total Service	47,759	23,862	23,897
Unemployed	<u>2,708</u>	<u>1,278</u>	<u>1,430</u>
TOTAL LABOR FORCE	80,617	46,778	33,839

In 1960, 5,567 people were employed in the manufacturing category of food and kindred products. About half of these people were employed in the meat packing industry which is centered in Sioux Falls, South Dakota. The success of this industry is the result of a good supply of animals being produced in the area, adequate transportation facilities for live animals and finished products and the well established terminal market. However, the terminal market influence is diminishing.

Sioux Falls, including its existing meat packing industry, is the major source of municipal and industrial wastes. Other sectors of the economy are not significant water users or waste producers.

Future

Meat packing will use more water and contribute more waste than any other industry in the study area through 2070. Most production increases are projected to be in the Sioux Falls area. Increases in livestock slaughter, however, are expected downstream from Sioux Falls in the Hawarden, Iowa, area. As more animals are slaughtered in the area of their production, this will result in a declining influence of the two terminal markets at Sioux Falls and Sioux City. Using an index of future beef and pork production requirements and the present slaughter capability, cattle and hog slaughter is projected for the study area in Table VI-3.

TABLE VI-3
CATTLE AND HOG SLAUGHTER 1960-2070
BIG SIOUX STUDY AREA

<u>Cattle</u>	<u>1959-61 Average</u>	<u>1970</u>	<u>2020</u>	<u>2070</u>
Head slaughtered per year	150,000	200,000	490,000	750,000
<u>Hogs</u>				
Head slaughtered per year	800,000	872,000	1,816,000	2,800,000

Source: Developed from unpublished data of the United States Department of Agriculture

Cattle and hog packing plant operations are locating closer to the supply of animals for slaughter. This decentralization trend of slaughter operations from terminal markets is expected to continue. This trend may work to the study area's advantage by attracting new packing plants since there are large numbers of animals available.

Agriculture will continue to be significant to the economy of the study area through 2070. Continued emphasis will be placed on production of slaughter animals in farm and commercial feedlots.

Except for the meat packing industry, manufacturing and mining will have insignificant roles in the study area throughout the projection period.

The service and trade industries are expected to have good growth in the study area through 2070 as the Sioux Falls area becomes a larger urban area.

The population increase is expected to continue in the urban areas.
Table VI-4 summarizes projected urban population growth.

TABLE VI-4
POPULATION PROJECTIONS FOR MAJOR URBAN AREAS 1960-2070
BIG SIOUX RIVER STUDY AREA

	<u>1960</u>	<u>1970</u>	<u>2020</u>	<u>2070</u>
Sioux Falls, S. Dakota	65,466	80,000	191,000	350,000
Hawarden, Iowa	2,544	2,800	3,400	4,100
Flandreau, S. Dakota	2,129	2,100	2,400	2,800
Dell Rapids, S. Dakota	1,863	2,000	3,000	4,000

VII. WATER QUALITY CONTROL

Municipal and Industrial Pollution

The status of municipal waste treatment is shown in Appendix 1. The study area includes the area below the Flandreau damsite, the Skunk Creek damsite, the Rock River damsite and the Little Rock River damsite. Plate 2 shows the locations of the municipalities.

Meat packing plants at Sioux Falls, South Dakota and Hawarden, Iowa contribute heavily to the pollution load. The wastes from Morrell Packing Plant and the Sioux Falls Stockyards are discharged into the municipal system. The Greenlee Packing Plant operates lagoons for waste treatment and discharges the treated effluent into an intermittent tributary of the Big Sioux River several miles above the Sioux Falls treatment plant. The wastes from Greenlee will be discharged into the municipal treatment system in the near future. A small meat packing plant at Hawarden, Iowa, presently discharges untreated wastes into the Big Sioux River. The addition of secondary treatment at the plant, combined with supplemental flows provided for Sioux Falls will insure good water quality below Hawarden.

Irrigation

The feasibility of irrigation in the Big Sioux River Basin is now being investigated. At the present time proposals call for an irrigation pool of 194,000 acre feet in Flandreau Reservoir to supply water for approximately 45,000 acres of irrigated land between the dam and the

mouth of the Big Sioux River. However, the amounts of land to be irrigated at specific locations have not been decided upon at this time.

Data for water years 1965 through 1968 from the Water Pollution Surveillance Station below Sioux Falls, South Dakota indicate that the sulfate concentration in the river varies from 23 to 420 mg/l with an average value of 224 mg/l. The total dissolved solids (TDS) concentration varies from 170 to 1,459 mg/l with an average value of 766 mg/l. These concentrations are based on strictly arithmetic averages from samples collected below Sioux Falls and have not been related to discharge.

The effects of the irrigation return flows on the Big Sioux River Basin have not been evaluated since the project is in its initial formulating stage. There will be an increase in TDS concentrations in the river because of evapo-transpiration losses associated with irrigation without considering the possibility of salt pickup in the reduced return flows. Chemical concentrations and nutrient levels will probably increase due to the use of fertilizers, pesticides and herbicides.

If irrigation storage becomes part of the project, the flow requirements for water quality control will have to be re-evaluated considering the effects of irrigation return flows.

Water Quality Criteria

Water quality goals for the study area are governed by the Water Quality Standards prepared by South Dakota and approved by the Secretary of the Interior. The Standards state that from the Sioux Falls Diversion

Ditch to Klondike Dam, which is located above Canton, South Dakota, the stream will be classified for the following uses: warm water marginal fish life propagation, limited contact recreation, wildlife propagation and immersion sports recreation in addition to wildlife propagation and irrigation. The standards of South Dakota also state that criteria on fishlife propagation will be changed from warm water marginal to warm water semi-permanent when supplemental water for water quality control is available. The dissolved oxygen requirement is 2 mg/l for the marginal use and 4 mg/l for the semi-permanent classification. Therefore, storage in the proposed reservoirs to provide releases for water quality control will upgrade the water quality standards to warm water semi-permanent fishery with a dissolved oxygen requirement of not less than 4 mg/l in the Big Sioux River below Sioux Falls, South Dakota. Discussions with the Omaha District, Corps of Engineers, has indicated that their present operating studies show a very small percentage of failure in meeting releases for water quality control. Continued review of operating criteria after the reservoirs are constructed will be necessary to assure that the water quality is maintained.

Flow Regulation

Storage for regulation of streamflow for the purpose of water quality control must not be provided as a substitute for adequate treatment or other methods of controlling waste at the source. Adequate treatment is considered to be efficiently operated secondary waste treatment plants obtaining a minimum of 85 percent removal of BOD from organic wastes.

Analysis of the effects of the present and anticipated waste loads in the Big Sioux River indicates that the critical oxygen sag will occur approximately 10 miles below Sioux Falls, South Dakota.

By maintaining required flows for the Sioux Falls discharges, adequate flows will be provided to maintain suitable water quality on all downstream reaches.

The amount of flow needed in the river above Sioux Falls to maintain 4 mg/l of dissolved oxygen downstream from Sioux Falls is given in Table VII-1. The municipal treatment plant at Sioux Falls, South Dakota presently removes approximately 95 percent of the BOD of the incoming sewage and industrial wastes which have a P.E. (population equivalent) of about 500,000 persons before treatment.

Storage Requirements

A river basin model developed by the Northwest Region, FWPCA, was used to compute the necessary flow to maintain the desired 4 mg/l dissolved oxygen (DO) concentrations below Sioux Falls.

Two reservoir sites are being studied upstream from Sioux Falls, on the Big Sioux River near Flandreau, South Dakota and on Skunk Creek near Hartford, South Dakota. Skunk Creek joins the Big Sioux River at Sioux Falls. The water necessary to maintain acceptable water quality below Sioux Falls may be released from these reservoirs. The minimum flow in cubic feet per second, required above Sioux Falls is shown in Table VII-1.

TABLE VII-1

FLows REQUIRED AT SIOUX FALLS
TO MAINTAIN 4 mg/l OF DISSOLVED OXYGEN
(cubic feet per second)

	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2020</u>	<u>2070</u>
Jan.	20	25	30	35	45	60
Feb.	20	25	30	35	45	60
Mar.	10	10	10	10	10	10
Apr.	10	10	10	10	10	10
May	15	15	20	20	25	35
June	25	25	30	35	45	65
July	40	45	50	60	85	140
Aug.	25	25	30	35	45	70
Sept.	20	20	20	25	30	45
Oct.	10	10	10	10	10	10
Nov.	10	10	10	10	10	10
Dec.	20	25	30	35	45	60

VIII. BENEFITS OF IMPROVED WATER QUALITY

Adequate water quality will provide favorable conditions for fishing and other water recreation without the nuisance of noxious odors, discolored water, and excessive turbidity. Tangible water quality benefits will be based on the improvement of water quality by flow augmentation in the Big Sioux River.

Late summer low flows and associated poor water quality in the Big Sioux River occur each year. This results in undesirable conditions below Sioux Falls discouraging recreational use of the river. The 1960 population of the study area is approximately 220,000 of which 65,000 people are in the Sioux Falls area. It is reasonable to anticipate that a large portion of the total population in the study area will be able to enjoy the recreational opportunities made available by the construction of reservoirs.

The Sioux Falls plant is presently averaging 95 percent removal of BOD. The wastes from Morrell and Company Packing Plant and the Sioux Falls Stockyards go through a complete secondary treatment cycle prior to being mixed with the domestic sewage. The combined wastes then go through an additional secondary treatment process.

In order to meet the water quality standards for the Big Sioux River by flow augmentation from the proposed reservoirs, benefits will be provided equal to the cost of achieving the desired quality by an

alternative method. Several methods should be considered, and the benefit will be equal to the cost of the method which may be provided most economically.

Holding ponds to store the plant effluent during times of low flows and then release the effluent during periods when the river is able to assimilate the waste have been feasible in other projects. However, the Big Sioux River is presently deficient, using nine out of 10 year low flow criteria, from June through October, and quite often is deficient in the winter during frozen periods. The flow in the Big Sioux is not of a large enough volume to allow the use of holding ponds.

Another alternative method studied has been to pipe the effluent from a treatment plant located on a small river to a larger river which can fully assimilate the effluent. In the case of Sioux Falls, the closest acceptable large body of water which would be able to handle the effluent is the Missouri River approximately 150 river miles from Sioux Falls and close to 60 overland miles. These distances prohibit the piping of the effluent to the Missouri River. The total cost, including principal and interest, of a 66-inch pipe to the Missouri River to carry the projected 50-year effluent would amount to over 10 million dollars.

A single purpose reservoir as a source of water for quality control on the Big Sioux would require storage of approximately 54,000 acre feet of which 16,000 acre feet would be required for sediment storage. The cost of supplying the water from a single purpose reservoir on the

Big Sioux would amount to \$263,000 per year. A single purpose reservoir on Skunk Creek to supply the additional flows would require storage of 40,500 acre feet including 2,500 acre feet for sediment. The cost of the reservoir on Skunk Creek would be \$272,000 per year.

Advanced waste treatment by final filtering of the Sioux Falls effluent is the most economical alternative to achieve the desired water quality in the Big Sioux River. The cost is computed by adding filtration facilities presently to handle the wastes until 2000. At that time, complete rebuilding and expansion of the facilities would be done to meet the requirements until the year 2030. Additional major rebuilding and expansion will be required to operate through the remaining part of the 100 year study period.

The cost of the advanced waste treatment as final filtering of the effluent is calculated for both 50 year and 100 year periods. The cost of the facilities over a 50 year period includes a capital cost of \$44,800 per year with an operation and maintenance cost of \$23,100 per year. The total cost over the 50 year period is \$67,900 per year amortized at 4-7/8 percent. The cost of the facilities over a 100 year period amounts to a capital cost of \$27,900 per year with operation and maintenance at \$36,200 per year for a total of \$64,100 per year over the 100 year period.

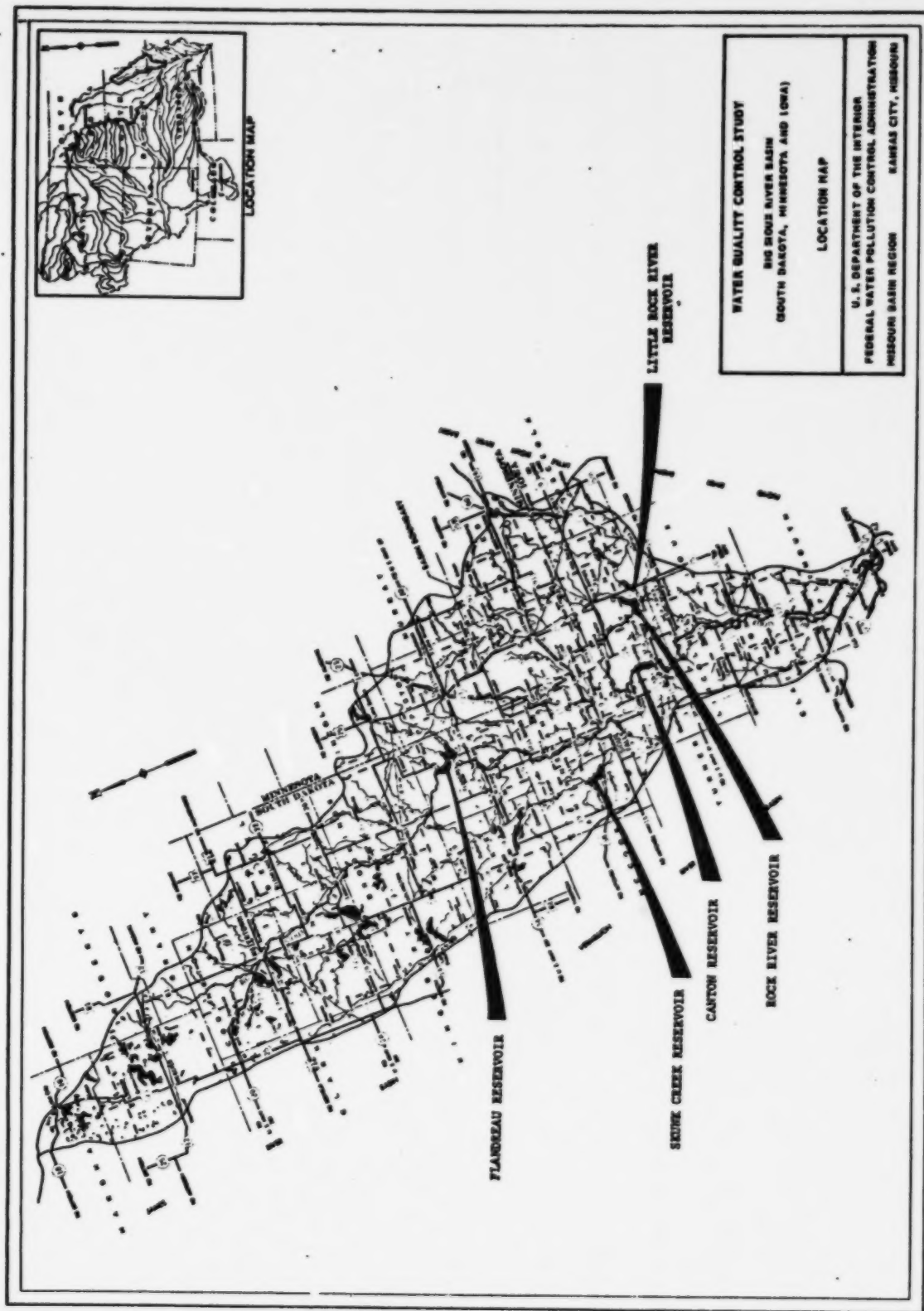
The benefits for water quality storage are considered to be equal to the cost of achieving the water quality by the most economically feasible alternate method, in this case, advanced waste treatment. The cost of all alternative methods considered in this report were amortized at 4-7/8 percent. A summary of the methods and costs for the benefit study is given in Table VIII-1.

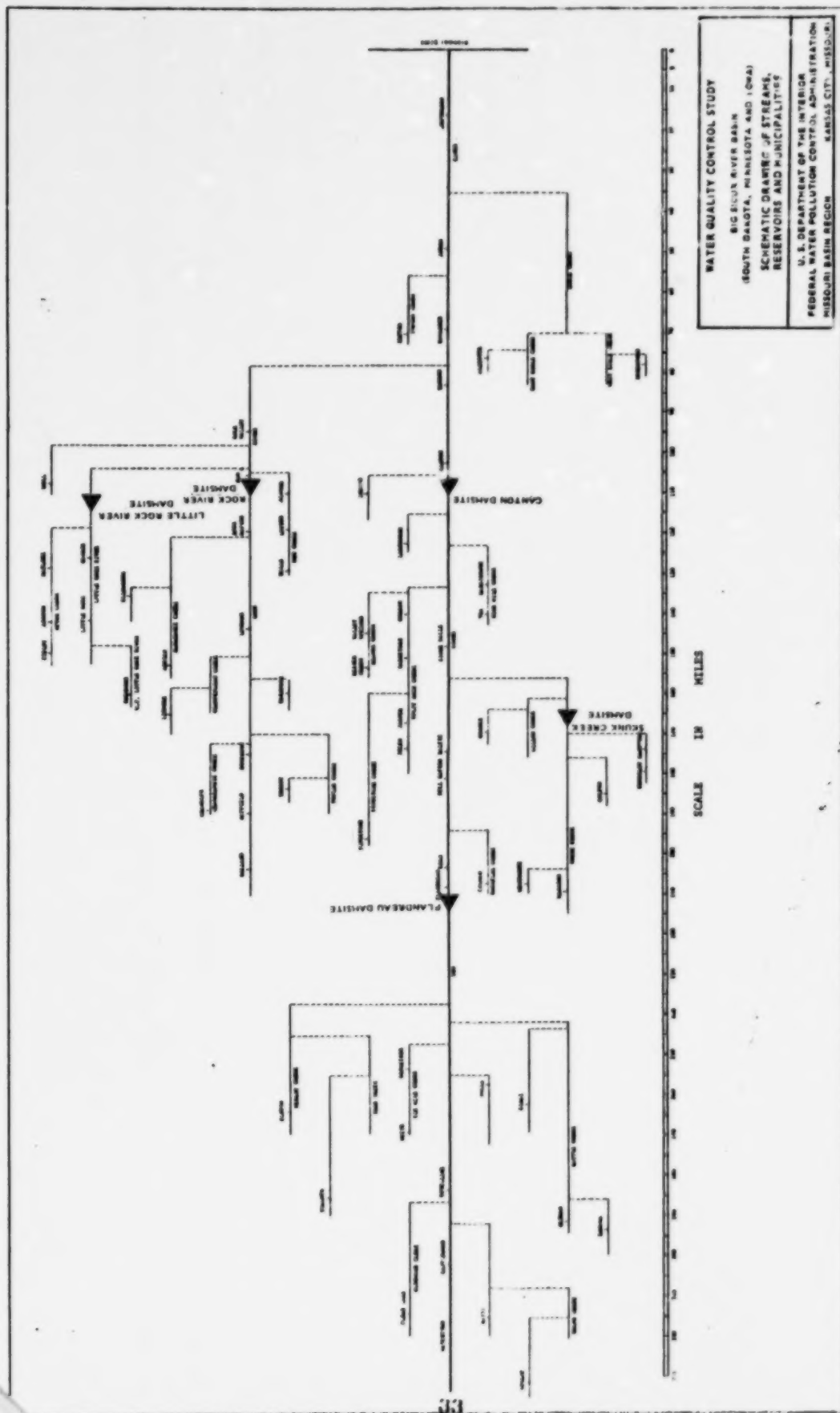
Table VIII-1

ALTERNATIVE METHODS FOR ACHIEVING DESIRED WATER QUALITY

<u>Alternative Method Studied</u>	<u>Adequacy</u>	<u>Total Cost (Principal & Interest)</u>	<u>Cost Per Year</u>
Holding ponds	not feasible		
Effluent piping (100 yrs.)	possible	\$10,000,000+	\$2000,000+
Single purpose reservoir on Big Sioux River (100 yrs.)	feasible	\$26,300,000	\$263,000
Single purpose reservoir on Skunk Creek (100 yrs.)	feasible	\$27,200,000	\$272,000
Advanced waste treatment at Sioux Falls, South Dakota (100 yrs.)	feasible	\$6,410,000	\$64,100
Advanced waste treatment at Sioux Falls, South Dakota (50 yrs.)	feasible	\$3,400,000	\$67,900

The benefits assigned for storage for water quality control are \$67,900 per year for a 50-year study period or \$64,100 per year for a 100-year study period. The benefits are considered to be widespread in scope and therefore nonreimbursable.





IX. BIBLIOGRAPHY

1. U.S. Bureau of Census, Census of Population, 1960, Volume I, "Number of Inhabitants," U.S. Government Printing Office, Washington, D.C., 1961.
2. U.S. Bureau of Census, Census of Population, 1960, Volume II, "Characteristics of the Population," U.S. Government Printing Office, Washington, D.C., 1962.
3. Economic Research Service, Unpublished Data, U.S. Department of Agriculture.
4. Worley, John Larry, A Systems Analysis Method for Water Quality Management by Flow Augmentation, U.S. Department of the Interior, Federal Water Pollution Control Administration, Northwest Region, Portland, Oregon.
5. U.S. Department of the Interior, Bureau of Reclamation, Report On Big Sioux Basin and Missouri Terrace Area, Missouri-Oahe Projects Office, Huron, South Dakota, January 1968.
6. U.S. Army Engineer District, Omaha Corps of Engineers, Review Report on Big Sioux River at and in the Vicinity of Sioux City, Iowa and North Sioux City, South Dakota, Volume 1, Report and Appendices, Omaha, Nebraska, March 1967.
7. Greeley and Hansen, Engineers, Sioux Falls, South Dakota, Report on Sewerage and Waste Treatment, Chicago, Illinois, November, 1965.
8. Herreid, John Mack, Appraisal of Water Quality Standards for the Big Sioux River Downstream from Sioux Falls, South Dakota, thesis submitted to South Dakota State University, College of Engineering, Brookings, South Dakota, 1967.
9. Naughton, Daniel Joseph, Relationship of Dissolved Oxygen Concentration with Flow, Temperature and BOD for the Big Sioux River Downstream from Sioux Falls, South Dakota, thesis submitted to South Dakota State University, College of Engineering, Brookings, South Dakota, 1968.
10. Missouri Basin Inter-Agency Committee, Streamflow Characteristics in the Eastern Dakota Tributaries, July, 1967.

11. South Dakota Committee on Water Pollution, Water Quality Standards for the Surface Waters of South Dakota, Pierre, South Dakota, February, 1967.
12. Iowa Water Pollution Control Commission, Water Quality Criteria and Plan for Implementation and Enforcement for the Surface Waters of Iowa, State Department of Health, Des Moines, Iowa, May 1967.
13. U.S. Department of the Interior, Geological Survey, Compilation of Surface Water Records of the United States through September 1950, Part 6-A, Missouri River Basin above Sioux City, Iowa, WSP-1309, 1958.
14. U.S. Department of the Interior, Geological Survey, Compilation of Surface Water Records of the United States October 1950 to September 1960, Part 6-A Missouri River Basin above Sioux City, Iowa, WSP-1729, 1964.
15. U.S. Department of the Interior, Geological Survey Surface Water Records of North Dakota and South Dakota, Water Years 1961, 1962, 1963, 1964, and 1965, U.S. Geological Survey, Pierre, South Dakota.

X APPENDIX

APPENDIX 1

Waste Treatment of Municipalities below Proposed Reservoirs

Municipality	1960 Population	Type of Treatment	Population Equivalent Raw	Population Equivalent Discharged	Discharge to:
<u>Minnesota</u>					
Beaver Creek	250	----	NO SEWERAGE SYSTEM	----	----
Hills	516	----	NO SEWERAGE SYSTEM	----	----
Ihlen	111	----	NO SEWERAGE SYSTEM	----	----
Jasper	850	Sec.	770	115	Split Rock Creek
Pipestone	5,324	Sec.	4,790	480	Pipestone Creek
<u>Iowa</u>					
Akron	1,351	Sec.	1,200	120	Big Sioux River
Alvord	238	----	NO SEWERAGE SYSTEM	----	----
Doon	436	Prim.	400	300	Little Rock River
Hawarden	2,544	None	2,500	2,500	Big Sioux River
Hull	1,289	Sec.	2,500	500	Unnamed Creek
Inwood	638	Sec.	600	250	Unnamed Creek
Ireton	510	Sec.	510	50E*	Indian Creek
Larchwood	531	----	NO SEWERAGE SYSTEM	----	----
Lester	239	----	NO SEWERAGE SYSTEM	----	----
Rock Valley	1,693	Sec.	1,500E*	800E	Dry Run

APPENDIX 1 (continued)

Municipality	1960 Population	Type of Treatment	Population Equivalent		Discharge to:
			Raw	Discharged	
South Dakota					
Alcester	479	Sec.	470E	75E	Brule Creek
Baltic	278	Sec.	270	27E	Big Sioux River
Beresford	1,794	Sec.	1,750E	150E	Ash Creek
Canton	2,511	Sec.	2,500	250E	Big Sioux River
Colman	505	Prim.	600E	400E	Bachelor Creek
Corson	50	----NO	SEWERAGE SYSTEM		
Crooks	135	----NO	SEWERAGE SYSTEM		
Dell Rapids	1,863	Sec.	1,850E	350E	Big Sioux R.
Egan	310	----NO	SEWERAGE SYSTEM		
Flandreau	2,129	Sec.	2,400E	400E	Big Sioux R.
Garretson	850	Sec.	840E	80E	Split Rock Creek
Harrisburg	313	----NO	SEWERAGE SYSTEM		
Hudson	455	None	450	450	Big Sioux R.
Jefferson	443	Sec.	440	44E	Missouri R.
Sioux Falls	65,466	Sec.	325,000	13,500	Big Sioux R.
Tea	188	Sec.	188E	19E	Nine Mile Creek
Valley Springs	472	Sec.	470E	47E	Beaver Creek

*Estimated

APPENDIX 2
WATER QUALITY CRITERIA
FOR THE
SURFACE WATERS OF SOUTH DAKOTA

APPENDIX 2 - WATER QUALITY CRITERIA FOR THE SURFACE WATERS OF SOUTH DAKOTA

Water Quality Parameters	A. Coliform Organisms (MPN or Equivalent MPN)	B. Dissolved Oxygen mg/l	C. pH (pH Units)	D. Turbidity (Jackson Candle Units)	E. Temperature (°F)	F. Temperature Change (°F)	G. Dissolved Solids	H. Visible Pollutants: Oil, Scum and Floating Solids; Sludge and Offensive Conditions
Beneficial Uses								
1. Domestic water supply with coagulation, sedimentation, filtration and disinfection or its equivalent	Not to exceed a MPN or MP of 5000/100 ml as a monthly average value; nor to exceed this value in more than 20% of the samples examined during any one month; nor to exceed 20,000/100 ml in more than 2% of the samples examined in any one month		Greater than 6.0 and less than 9.0 (a) Section II 3.				Total Dissolved Solids-1000 mg/l (c)	Section II 1. Visible Pollutants. No raw or treated sewage, garbage, industrial wastes or agricultural wastes shall be discharged into any waters of the State which produce floating solids, scum, oil slicks, material discoloration, undesirable odors, visible gassing, sludge deposits, alimes, fungus growths or other offensive effects.
2. Fish Life Propagation								
a. Cold Water Permanent	See #3b	Greater than 4.0 (a)	Section II 3. 4. 6.6 - 8.6 (a)	25 (c)	68 (a)	4 (a)		Section II 1.
b. Cold Water Marginal		" 3.0 (a)	6.5 - 8.8 (a)	50 (c)	75 (a)	4 (a)		"
c. Warm Water Permanent		" 4.0 (a)	6.5 - 8.8 (a)	50 (c)	85 (a)	4 (a)		"
d. Warm Water Semi-permanent		" 4.0 (a)	6.3 - 9.0 (a)	100 (c)	90 (a)	8 (a)		"
e. Warm Water Marginal		" 3.0 (a)	6.0 - 9.3 (a)		92 (a)	8 (a)		"
3. Recreation								
a. Immersion Sports Swimming, Water Skiing, Skin Diving and other water sports	Not to exceed a MPN or MP of 1000/100 ml as a monthly average; nor to exceed this value in more than 20% of the samples examined in any one month; nor to exceed 2400/100 ml on any one day during the recreation season.	Greater than 2.0 (a)	Section II 3. Acids and alkalis. With the exception of those water-courses in the Intermittent Stream category, no materials shall be discharged from any one source which shall affect the pH of the receiving waters by more than 1.0 unit within the limits specified herein.					Section II 1.
b. Limited Contact Recreation Fishing, Boating, Sailing, Picnicking and other water related recreation	Not to exceed a MPN or MP of 5000/100 ml as a monthly average; nor to exceed this value in more than 20% of the samples examined in any one month; nor to exceed 10,000/100 ml on any one day during the recreation season.	" 3.0 (a)						
4. Wildlife Propagation and Stock Watering			Greater than 6.0 and less than 9.5 (a) Section II 3.				Total Dissolved Solids-2500 mg/l (c) Electrical (c) Conductivity-4000 micro-mhos/cm @ 25°C	Section II 1.
5. Irrigation	The MPN or MP shall not exceed 5000/100 ml as a monthly average; nor shall the number exceed 10,000/100 ml in any one sample. (Root crops and recreation)		Section II 3.				Total Dissolved Solids-700-1500 mg/l Electrical (d) Conductivity-1000-2500 micro-mhos/cm @ 25°C Sodium Adsorption Ratio - 10-26 (d) Soluble Sodium % - 20-70% (d)	Section II 1.
6. Commerce and Industry Cooling, industrial process, navigation, power			Greater than 6.0 and less than 9.5 (a) Section II 3.				Total Dissolved Solids-2000 mg/l (c)	Section II 1.
7. Intermittent Stream	Not to exceed a MPN or MP of 20000/100 ml as a monthly average value; nor to exceed this value in more than 20% of the samples tested in any one month; nor to exceed 50,000/100 ml in any of the samples tested.		Greater than 6.0 and less than 9.5 (a)					Section II 1.

Notes:

1. For full comprehension and justification of the objectives in this table, reference must be made to the accompanying text.
2. Qualitative and quantitative evaluations of water samples for comparison with these objectives should be made in accordance with the procedures set forth in Standard Methods for the Examination of Water and Wastewater-1965, published by the APHA, the AWWA, and the WPCF or by methods prescribed by the Committee.

I. Toxic Materials: Pesticides, Herbicides and Related Organic and Inorganic Compounds	J. Radioactive Materials	K. Biochemical Oxygen Demand (5 day 20°C) mg/l	L. Suspended Solids mg/l	M. Nitrates mg/l	N. Alkalinity (CaCO ₃) (Total) mg/l	O. Cyanides (CN) mg/l	P. Chlorides (Cl) mg/l	Q. Hydrogen Sulfide (H ₂ S) mg/l	R. Iron (Total Fe) mg/l
Section II 3. Toxic Materials. No materials shall be discharged to any surface water or watercourse in the State which produce concentrations of chemicals toxic to humans, animals or the most sensitive stage or form of aquatic life greater than 0.1 times the acute (96 hour) median lethal dose for short residual compounds or 0.01 times the acute median lethal dose for accumulative substances or substances exhibiting a residual life exceeding 30 days in the receiving waters. Acute median lethal concentrations shall be based on the results of the most recent research results for the material being studied or, in case of disagreement, by bioassay tests simulating actual stream conditions run in accordance with procedures outlined in "Standard Methods for the Examination of Water and Wastewater-1965" published by the American Public Health Association and using test animals or organisms specified by the Committee. Concentrations specified for toxic materials shall be based on daily averages, but the concentrations shall not exceed 125% of the value specified at any time or in any section of the receiving water. These provisions shall not apply to those toxic materials for which specific limits are specified in the criteria for given beneficial uses. Section II 4. Taste and Odor Producing Chemicals. No materials shall be discharged which will result in concentrations in the receiving water sufficient to impart objectionable tastes and odors to edible aquatic life.	Section II 3. Radioactive Materials. Radioactive materials shall not be permitted in the waters of the State unless these materials are readily soluble or dispersible in water and in quantities determined by the Committee to be in accord with criteria of the South Dakota State Department of Health or other appropriate State or Federal Agency.			10 as N (a) 45 as NO ₃ (a)					
			30 (a) 90 (a) 90 (a) 90 (a) 150 (c)			0.02 (a) 0.02 (a) 0.02 (a) 0.02 (a) 0.05 (a)	100 (c)	0.3 (a) 0.5 (a) 0.5 (a) 1.0 (a) 1.0 (a)	0.2 (b) 0.2 (b) 0.2 (b) 0.2 (b)
	Section II 3.								
	Section II 3.			50 as NO ₃ (b)	750 (c)				
	Section II 3.								
	Section II 3.								
	Section II 3.								
	Section II 3.	30 (b)	30 (b)						
FREQUENCY CODE a The value specified shall be maintained at all times without exception. b The value specified shall be maintained at all times based on results of composite samples collected over a 24 hour sampling period. In addition, the concentration of the pollution characteristic shall not exceed 1.75 times the value specified for the material in any one grab sample collected during the sampling period. c The value specified shall be maintained at all times based on the average of composite or grab samples collected in a manner approved by the Committee over a 3 day period. In addition, the concentration of the pollution characteristic shall not exceed 2 times the value specified for the material in any one grab sample collected during the sampling period. d The value specified shall be maintained at all times based on the average of composite or grab samples collected in a manner approved by the Committee over a 30 day period. In addition, the concentration of the pollution characteristics shall not exceed 3 times the value specified for the material in any one grab sample collected during the sampling period.									